HISTORY OF THE ARTESIAN WATER SUPPLY AT SAVANNAH, GEORGIA[1]

By E. R. Conant

Savannah, the county seat of Chatham County, Ga., has a population of 80,000. The county is in the eastern section of the coastal plane, and has an area of 370 square miles. Savannah is 18 miles from the sea coast and is on the south bank of the Savannah River, and the elevation of the city above sea level ranges from 14 to 40 feet.

Historical. Previous to 1854, when the city had a population of 15,000, the domestic supply was obtained from wells ranging in depth from 15 to 30 feet. They were of the ordinary circular type lined with stone or brick, and ordinary hand pitcher pumps were placed at the top of them. The city maintained these wells and pumps, and the records show that the annual expenditures for obtaining a ground water supply by maintaining some 150 wells, ranged from $3000 to $7000. The records state that the water furnished was soft and wholesome, but in one of the old city reports, it was stated that mulberry trees growing anywhere near these wells were required to be removed, because they affected the purity of the water, in what way the author cannot imagine.

The city also constructed and maintained approximately twenty large brick cisterns under ground, each with a capacity of from 5000 to 10,000 gallons, which were kept filled for fire service only. These were abandoned many years ago, but the author in paving a street recently discovered one of these old cisterns and after opening it at the top found it to be partially filled with clear water, and there was no algae growth on the walls. The cistern was entirely closed, the water entering it by percolation through the brick. Unfortunately no bacteriological analysis was made of the water to ascertain whether it was potable.

In 1851, the mayor and aldermen engaged the services of A. W. Craven, chief engineer of the Croton water works, New York, as consulting engineer to design a project for obtaining a surface water

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supply from the Savannah River. This supply was put in operation in 1854, and the author found in one of the old reports that the first Worthington type of pumping engine was installed at Savannah under this project. Water partially filtered was taken from the Savannah River at a point opposite the thickly populated portion of the city, and pumped to a standpipe, from which it was distributed by mains over a portion of the city. After twenty years operation of this plant, it was believed that the health conditions of the city would be improved if the intake at the river was further from the city proper, and a new pumping station, locally known as the river station, was constructed at a point $1\frac{3}{4}$ miles up the river, and this station was used for pumping direct from the river until 1887, when an artesian well supply was adopted.

Introduction of artesian wells. In 1879 the mayor of the city brought up the question of the possibility of obtaining a water supply by boring artesian wells. Little was known of artesian wells at this date and for a number of years the city authorities were skeptical of obtaining a suitable supply by this method. As far as the author can learn the earliest artesian or deep well in Georgia was bored in Savannah in 1882, and the boring of others soon followed, as they were self-flowing and furnished a most desirable quantity of water. The agitation for obtaining an artesian well supply for Savannah resulted in the boring of several wells, and at the end of 1887, 15 wells had been bored near the river pumping station alluded to above, and a small reservoir was constructed into which the water from the wells entered by gravity, and the city's supply was obtained from these self-flowing wells. With a diminution of the flow, due to the lowering of the static head, the wells failed to furnish the necessary supply, and to make up the deficiency a portion of the supply was taken from the Savannah River and temporarily mixed artesian and river water was used.

Geological data. The Atlantic coastal plane reaches from New York to the Florida straits. This plane is underlaid by a great sediment of superficial deposits consisting of gravel, sand, clay, marl and loam, and in certain localities lime rock full of cavities exists, which forms the aquifer into which the water pours from the catchment areas through a stratum of sand beds, which have a general seaward dip. These aquifers form valuable underground water resources. Along the coast of Georgia there is a strip 25 to 40 miles wide bordering the coast overlying water-bearing strata or aquifers through which water

comes from a catchment area located from 80 to 100 miles northwest of this coast line. The character of the water obtained from the aquifer along the Georgia Coast is in almost every instance potable and suitable for a domestic supply, and at this time there are over 1000 wells tapping the aquifer in this state alone. The direction of the flow from the catchment area to the aquifer at this locality is in a southeastern direction, and it is observed that the interference of one well over another is less when they are bored on an axis perpendicular to the line of flow than where they are promiscuously bored, as was the case with the first artesian well supply at the river pumping station, above referred to.

The strata penetrated in boring artesian wells at Savannah consist of 250 to 300 feet of clay with interbedded layers of marl and sands, and under this from 220 to 250 feet of porous limestone, or more strictly speaking, limestone with voids or cavities. The principal water-bearing stratum is in the limestone. Below this, for 300 to 350 feet, a formation of marl intermixed with some shell is found until a shallow stratum of flint rock is struck at about 950 feet below the surface. Below this, for a depth of 50 feet, is another water-bearing stratum of limestone similar to the upper aquifer.

Gwinnett Street pumping station. As noted above the supply at the river station was insufficient to meet the needs of the city, and in 1891 a new project was adopted for supplying it with artesian water, which project at the time was one of the most carefully planned of any in the country. The site selected for the new pumping station is two miles southeast of the river station, well within the corporate limits of the city. The city employed as consulting engineer, Thomas F. Johnson, of Chicago, who at the same time was installing an artesian supply at Memphis, Tenn. The plan here consisted of boring 12 wells 300 feet apart in a continuous line nearly perpendicular to the line of the subterranean flow. The depth of the wells is from 500 to 600 feet. They are all 12 inches inside diameter, and the casing is driven to a depth of approximately 250 feet, where it is imbedded in rock so that there can be no contamnation of the aquifer from surface water following the casing. A brick conduit 6 feet in diameter was constructed from 10 to 16 feet below the surface of the ground on a level grade, with elevation at mean low water, into which the wells flow, and the water is carried through this conduit to the pump well at the station.

The pumping equipment consisted of two Holly engines of the Gaskill type of 10,000,000 gallon capacity each. A 42-inch main was laid from the pumping station to the edge of the thickly populated section of the city, 4000 feet distance. This station is $\frac{3}{4}$ mile from the center of the water supply distribution. No standpipe or reservoir was provided, and at this date there is no standpipe or reservoir other than a small pump well which has a capacity of 40,000 gallons, and the brick conduit, which has a capacity of approximately 600,000 gallons. This pumping station was put in operation in 1893, and has been in continuous use without interruption since then.

When the Gwinnett Street station was put into operation the river station was shut down, and was not utilized, except for emergency use, for 11 years, and since then this station has only been used to make up any deficiency in supply that the Gwinnett Street station could not furnish with one pumping unit, the supply from the river station being about 10 per cent of the total consumption. The wells at the Gwinnett Street station were at first self-flowing, but the flow gradually lessened and an air lift plant was installed in 1902, consisting of two Ingersoll-Rand air compressors of 1800 cubic feet capacity of air per minute. In 1908 a single air compressor of 1200 cubic feet per minute capacity was installed at the river station. The method of operation at the Gwinnett Street station, is to work one unit for a month, then shut down this unit and operate the other, except in case of fire, when an increased supply is required, then both engines and compressors are immediately put in operation. The river station is only operated during the day, except when a peak load has to be provided for.

Static head of wells. When artesian wells were first bored in and near Savannah, the water rose to from 30 to 35 feet above mean low water. With a continuous draft upon the aquifer, the static head fell, and the rate and amount of lowering of the static head depends largely upon how concentrated the draft on the aquifer is at any locality. Take, for instance, the river station where 25 wells were bored promiscuously within a 10-acre tract. Records do not give the fall in the static head at the river station after the wells were first bored, but the diminution of the flow that occurred would indicate that within three years after they were put in operation the static head dropped at least 20 to 25 feet. Artesian wells were bored at the river station in 1887–1889, and between that year and 1893, the domestic supply, with the exception of a small percentage of pumpage

at times from the river, came from these wells. With the construction and operation of the Gwinnett Street station in 1893, the river station was shut down, excepting for very brief periods, until 1909. Since 1909 both stations have been in operation, but only from 1,000,000 to 4,000,000 gallons daily has been drawn from the wells at the river station; therefore, there has only been a light draft on the aquifer at this locality, and the elevation of the static head has changed but little.

At this time the elevation of the static head at the river station is from 4 to 6 feet above mean low water, whereas at the Gwinnett Street station, only 3900 feet away, where there is heavy continuous draft upon the wells, the static head of the 12 wells adjacent to it averages 12 to 14 feet below mean low water. Sufficient data have been collected to show approximately the rate of lowering of the static head at this station from 1893 to the present time, and if the fall in the static head was graphically shown, the line showing the lowering of the static head would form a parabolic curve with the flattening out of the curve occurring at this time.

In 1890, when the wells were first bored at the Gwinnett Street station, the static head there was approximately 28 feet above mean low water, and the static head of the original wells bored in this vicinity was approximately 35 feet above mean low water so that the operation of the wells at the river station previously to the boring of the wells at the Gwinnett Street station evidently effected to some extent the water pressure in the aquifer at the Gwinnett Street station. Three years after the wells were first put in operation at the Gwinnett Street station, the static head fell 12 feet, and five years later the static head had fallen 5 feet further. Unfortunately there is no record of the elevation of the static head in 1902, when the air compressors were first installed, and not until 1915 was the static head carefully determined by the author, when it was found to be from 10 to 12 feet below mean low water. In other words, during the last 17 years, the static head at the Gwinnett Street station has dropped approximately 22 feet, equivalent to an annual drop of somewhat less than $1\frac{1}{2}$ feet.

Assuming that a still further flattening of the curve of the static head lowering occurs, it will be a long time before the drop will fall to such an extent that the cost of obtaining water either with electrically driven pumps or with an air lift system will be excessive. With the present air lift system the additional cost per million gallons

pumped per each foot of sinking of the static head is 15 cents. Undoubtedly a continuous heavy draft on the aquifer will cause a continued lowering of the static head, but if there should be an interruption in pumping for any length of time the static head would return to an elevation considerably above mean low water. Wells just bored on the prolonged axis of the existing wells and distant 900 and 1600 feet from the nearest old wells have the elevation of the static head at approximately low water. New wells that have been bored within a distance of 2 or 3 miles of the river station are self-flowing at this date.

In connection with the static head it is necessary to consider the draw-down, which is proportional to the draft placed upon the wells. The draw-down at the Gwinnett Street station wells is from 12 to 15 feet, and at the river station approximately 6 feet, but if the air is cut off, the water rises rapidly to its ordinary static head elevation.

Interference of wells. As stated above, the wells at the river station were bored promiscuously in a small area, without any relation to the line of flow of the aquifer, and the wells interfere one with the other much more than at the Gwinnett Street station. Nine months ago a new well was bored within 90 feet of the one of the old wells at the Gwinnett Street station, and there has been very little interference between the two.

The static head has apparently only dropped 2 feet at this point, due to the additional draft on the aquifer. That this well has not interfered more with the old wells near it, can only be explained by the fact that the new well is a little deeper and evidently enters pockets that the old well does not draw from. We have one deep well 1500 feet deep, within 1000 feet of one of the old wells, which taps two aquifers. The static head is higher and the draw-down in this well is very much less than in the other wells.

Capacity of wells. While the aquifer has been tapped for a period of twenty-nine years, there is just as much water in the aquifer at this time as there was originally, as shown by the capacity of the wells, but it is necessary to go a little lower for the supply. When the wells were first bored at the river station the capacity of the 22 wells was approximately 6,000,000 gallons and it is easy to obtain this quantity now. Reference to the capacity of the wells at the Gwinnett Street station for various periods gives better data as regards the strength of the aquifer. When the 12 wells at the Gwinnett Street station were

bored in 1892, the total flow from it was 10,300,000 gallons per day. In a year or two this flow diminished to 9,500,000 gallons and in 1897 the records show the flow to be further reduced to 5,500,000 gallons. In 1900 the flow was slightly less, recorded as 5,000,000 gallons, and in 1902 the flow was approximately the same, but when the air lift system was introduced in 1902, the capacity of the wells increased to 10,300,000 gallons per day. Tests made by the author of the capacity of the same wells in 1915 showed the supply to be at the daily rate of 15,000,000 gallons, and at this date the city is obtaining this quantity without any effort, in fact at this time it is pumping from 8 wells and obtaining 10,000,000 gallons per day. This shows that there is a great subterranean flow, which is believed to be inexhaustible, and all that is needed is for a suitable distribution of wells to draw water without creating a too concentrated draft on the aquifer. The air is applied to the wells through 2½-inch pipe with no nozzles or air pump at the lower end, and the submergence is around 60 per cent. Not a well has been lost since they were first bored, this being due to the wells entering a limestone formation where there are no heavy pockets of sand.

Before the installation of the air lift, attempts were made to increase the flow of the wells by dynamiting, which produced no appreciable benefit. Another method was attempted of applying water under pressure to the wells. This was done by laying an 8-inch main along the axis of the wells and connecting the well with it. This flushing did increase the flow for the time being about 12 per cent. The running pressure of air at the wells at this time ranged from 22 to 30 pounds, with 45 pounds air pressure at the station.

Chlorine contents. One feature with artesian wells that requires attention is the possibility or probability of salt water entering the aquifer as the static head is lowered. It so happens that several analyses of artesian water were made in 1893 and the chlorine content of the water at that time was found to be 6.1 parts per million. In 1915 the chlorine content was found to be 6.2 parts per million, showing that up to this date there had been no increase in the salinity of the water. The wells that go to the lower aquifer reach a water of slightly different chemical analysis, the chlorine contents being about 14 parts per million.

Analyses of water from the artesian wells at Tybee, fifteen miles distant, which is on the sea coast, show the chlorine contents to be 6¼ parts per million, so that apparently there is no fear of the water

at Savannah becoming too salty for potable or domestic use for a long time to come.

Tidal interference. There is some oscillation in the static head of some of the wells, corresponding to the rise and fall of the tide at the sea coast, and this amounts in some localities to about 4 feet. It is not appreciable in the wells at the Gwinnett Street station, where water is drawn from the aquifer all the time. At the river station, when there is cessation in the pumping, the static head varies somewhat, and other wells in the county that are self-flowing have a stronger flow when the tide is high than when the tide is out.

Consumption of water. Savannah at this date has a population of approximately 80,000. The average consumption is 10,300,000 gallons per day, or a per capita consumption of 129 gallons. The consumption has fluctuated in the past from 115 to 165 gallons. This has been due in part to abnormal pumping during extraordinary cold spells and the extension of house drainage system, but especially to the large waste due to faulty plumbing.

A pitometer survey was made in Savannah in 1912 and considerable saving in pumpage was brought about by the work done following this survey. In the mains the pressure, which at one time was 30 pounds, has been increased to 50 pounds. The city has commenced the installation of meters and has passed an ordinance requiring stop and waste cocks on all risers. It is carrying out house to house inspection of all plumbing fixtures. The installation of only 700 meters last year brought about 4 per cent reduction in the per capita consumption.

Fuel consumption. Accurate records have been kept of the fuel consumption at the Gwinnett Street station since it was first put in operation in 1893. When the new pumps were first installed the consumption was 2000 pounds per million gallons pumped into the mains. Rather singularly the consumption sank regularly for a period of five years when 1450 pounds of coal pumped the same amount of water. This was during the period whem the wells were self-flowing. The lift from the pump well is approximately 12 feet and the pressure in the force main was at that time from 20 to 30 pounds. The installation of the air compressor increased the amount of fuel required to 2600 pounds of coal per million gallons pumped into the mains, but after efficiency was brought about in the operation of the air lift, the fuel required fell to 2100 pounds. From 1904 to 1914 the annual increase in consumption of coal has been 90 pounds per mil-

lion gallons pumped. This, of course, is accounted for by the slowly receding elevation of the static head, to the machinery becoming older and to the increase in pressure in the mains from 30 to 50 pounds, so that at this time the consumption is 3240 pounds of coal per million gallons.

The city's destructor plant, which destroys the city's refuse, was put into operation in March, 1914, and is operated by steam furnished by burning the refuse. The excess steam not required to operate the plant itself is conveyed from the boiler to the main boiler head at the pumping station. This excess steam for three years and nine months has resulted in the saving of $26,100 worth of coal, and if there was enough refuse to operate the destructor plant at its full capacity, the saving for this period would have been about double this amount. This total cost of operating the station, including maintenance, fuel and incidental expenses not excluding interest on investment, depreciation, or allowing for any sinking fund, has been on the average of $12. per million gallons pumped. At this time with abnormal conditions, the operating cost has risen to $16. per million gallons.

Deterioration of well casing. Investigation made of one well casing removed from the River Station showed it had suffered deterioration. On account of slight contamination of the water occurring at the river station two years ago, a thorough investigation was made to ascertain how this occurred, and this investigation has shown beyond a doubt that infiltration of surface water occurs through some of the well casings. In order to prove this, an attempt was made to withdraw one 10-inch casing and with the application of two 100-ton jacks the author succeeded in withdrawing 150 feet of the pipe, which then broke off at this depth. In the casing, at a point about 40 feet below the surface, a hole was found which it was thought at first might be due to electrolysis but was finally concluded to be due to corrosion. At present, to avoid contamination of the water, in the morning before pumping occurs into the mains, it is customary to apply the air compressor and waste the water from the wells for a period of one hour. This eliminates the accumulation of infiltered water through the previous night and with this operation there has been no trouble, as continuous pumping creates internal pressure in the casing greater than the outside pressure, thus keeping out infiltration. These casings have failed after 26 years life, and it has been planned to do away with this station within a few months.

The plan for improving the Gwinnett Street station includes the installation of electrically operated pumps of $1\frac{1}{2}$ million gallons daily capacity, thoroughly overhauling the present machinery, and setting additional meters to reduce the waste, so that the one station with one unit will supply the present demands.

Cost. The construction of the river station, which was met by a bond issue, cost $220,000; other outlays, such as the cost of the air lift system, for this station have been $57,000.

The initial cost of the Gwinnett Street station was $427,000, and since its construction to the present date $80,000 was expended for air lift plant and for new wells, making total construction cost $784,000.

Financial management. With the exception of one bond issue of $200,000, to pay for the first construction in 1882, all costs of construction, maintenance, extensions and renewals have been paid from the current revenue derived from the sale of water.

The management of the water works of this city has not been unlike the management of many municipalities, in that no sinking fund has been provided and any excess revenue over the expenditures for outlays or operation has been thrown into the treasury and used for any municipal use. No charge has been made against various departments for water furnished; the city has been exceedingly liberal as regards free water and only recently has taken proper steps to prevent and avoid wastage by the consumer.

From 1882 to the end of 1917 the revenue from the water works department has been in round figures $3,359,000. The total expenditure for the operation and maintenance for this period was $1,320,500; for construction of plant and mains and installation of air lift system, boring and connecting wells, a total of $1,328,500 was expended.

The cost of construction, boring of wells and connecting them, amounted to $1,328,500. An inventory of the water works department made by the author at the end of 1917 places the value of the physical portion of this department at $826,950; therefore, the depreciation is estimated at $501,550.

The total outlay for the past 36 years was $2,649,000, giving a surplus, excluding depreciation, of $710,000, or a net surplus, allowing for depreciation, of $208,450. There are no outstanding liabilities and the plants have been fully paid for. If the plant was privately owned, interest on investment would have to be considered, but this is more than offset by the public and free service that has been given.

It can be seen that rates for water have been fixed very closely to what has been required to meet the expenditures, but there should have been a sinking fund provided. Had there been a sinking fund the much-needed rehabilitation and extension of the water works system could be carried out at this time without recourse to a bond issue, which will be required within the very near future.

The per capita income is very much less than the average per capita income of other municipalities. In Savannah it is somewhat less than $2.00 per year per capita, while the average in the United States is about $2.50 per capita.

The total pumpage for 26 years was 97,408,000,000 gallons, making the total cost per million gallons pumped, including cost of construction, maintenance, all outlays, including extension of mains, etc., $27.20.